UNRESOLVED TRITIUM ISSUES IN THE MAGNETIC FUSION ENERGY PROGRAM

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ABSTRACT

This paper discusses twelve issues involving tritium in the Magnetic Fusion Energy Program that remain to be resolved. The issues are discussed in three broad categories: fuel reprocessing issues, detritiation issues, and tritium handling issues. Where appropriate, suggestions are made concerning routes to resolution of the issues.

INTRODUCTION

Tritium technology needed for magnetic fusion machines is under development at several laboratories worldwide[1], the earliest and most extensive of these being the Tritium Systems Test Assembly (TSTA) at the Los Alamos National Laboratory. As a result of this on-going work and the technical base inherited from previous national programs, developed tritium technology can be available by the time it is needed. Nevertheless, at present a number of important tritium issues are unresolved and in need of laboratory attention, program planning attention, policy decisions, international coordination, or some combination of these. This paper discusses the unresolved issues and, where appropriate, suggests paths toward their resolution.

The issues are enunciated as seen by the authors. However, the ideas, of necessity, are also the product of gathering and sharpening by interchange with the entire fusion and tritium communities. A formal example of this interchange is the current DOE-sponsored FINESSE study centered at UCLA.

The twelve issues fall into three general categories. Issues will be discussed here as they relate to those categories; namely, fuel reprocessing, detritiation, and tritium handling. A large category of issues not included, though tied to tritium, is breeding blanket issues, which, except for the interface with fuel reprocessing, is considered a separate subject. No order of importance is attached to the discussion.

FUEL REPROCESSING ISSUES

The largest category of tritium issues is that related to the integrated fuel processing loop. We list six items in the category.

Low-Flow Fuel Loops

Because of the direction taken by the current fusion program, near-term experimental machines will be limited in both tritium inventory and flow rates to quantities substantially less than the full-scale (1 kg per day tritium) flows for which TSTA was designed. Fuel loops for near-term machines likely will operate in batch rather than continuous modes. In most cases, technologies suitable for one mode are equally suitable for the other, although designs, of course, will change.

The exception is the hydrogen isotope separation system. For batch operations and low flows and inventories, the continuous, cryogenic distillation used at TSTA has attractive competitors. A leading one is palladium chromatography. Some effort is needed to design and test such a component for fusion applications. TSTA has a modest effort under way.

Tritium Process Losses and Breeding Requirements

More must be known about the overall efficiency of tritium utilization in all parts of the fusion facility and processes. Any unrecovered recurring losses of tritium though leakage or in waste streams must be made up by increasing the tritium breeding requirements for the lithium blanket, which could significantly affect design.

Nonrecurring losses will increase the tritium required for startup, but obviously will have less influence on breeding requirements than recurring losses. Examples of nonrecurring losses are the saturation level of tritium incorporated in the structure of molecular sieve material or a residual amount of tritium that cannot be recovered from uranium tritide storage beds.

Virtually all recurring losses are potentially recoverable and recyclable to the fuel stream, but at a cost. Losses associated with the reprocessing of plasma exhaust gases will be measured at TSTA. Also much will be learned there about the general losses from leakage and maintenance in tritium piping.

Filtering Activated Particulates from Reactor Exhaust

For two reasons, activated particulate matter (compounds of Fe, Ni, V, etc.) must be trapped or filtered out of reactor exhaust gases before they enter the fuel reprocessing equipment. Fine particles are damaging to the special (scroll and metal bellows) transfer pumps used in reprocessing. Of broader implications, activated particles in these systems would cause major problems by necessitating remote handling and maintenance equipment that would not be required if tritium is the only radioactive species present.

The use of high efficiency particulate filters (HEPA filters) for particulate removal is expected to be straight forward, but must be verified. Operation of filters in lines following cryopumps must be demonstrated.

Interface Between Blanket Systems and Fuel Reprocessing

When a breeding blanket system is designed and a tritium extraction technique selected, effort will be needed to design and test the interface between these blanket systems and the fuel reprocessing loop. This may require additional fuel cleanup systems and/or isotopic separation or enrichment systems. The latter could be especially important if there is a significant amount of hydrogen, ^1H, in the tritium stream extracted from the blanket. TSTA personnel have designed distillation processes for this application. If tritium is extracted from the blanket in the oxide form, HTO or T_2O, systems must be designed and tested for decomposing the oxide and recovering tritium in the molecular form.

Interface Between Coolant Detritiation and Fuel Reprocessing

Several unresolved questions are contained in the broader issue of determining the interface between the detritiation of water coolant and the processing of the extracted tritium for reuse in the fuel stream. The permeation or leakage of tritium into the coolant, the permeation or leakage from the coolant to other areas, and the acceptable (or affordable) level of detritiation achieved all play a part in determining both the design of the detritiation process as well as the resulting interface configuration with the fuel reprocessing loop.

Initially, answers must come from the permeation studies under way and the water detritiation work, including the industrial scale processes planned at Ontario Hydro, before detailed study of the interface with fuel reprocessing will be very fruitful. Later the interface should be designed and tested, either at a detritiation facility or the fuel reprocessing facility (TSTA), or both, as proves appropriate at the time.

Composition of Plasma Exhaust and Breeder Product

The plasma exhaust and breeder product are both inputs to the fuel reprocessing loop. The composition of the inputs affects the design of the loop. But these inputs now are not well characterized.

In the TSTA fuel reprocessing loop, an effort was made to design for the maximum concentrations and variety of impurities that might be present in a plasma exhaust. That effort still appears to have been successful.

At TSTA, we have also looked at designs of an additional distillation column that would be needed for stripping protium from the breeder product before that stream could be further processed by the existing reprocessing loop. If the breeder product is largely the oxides, additional steps will be needed to free the hydrogen isotopes.

We at TSTA seek further exchange of information with those working in the areas of plasma exhaust and breeding blankets.

DETRITIATION ISSUES

Effects of Combustion Products On Air Detritiation Systems

Accident scenarios in which tritium is released to the reactor hall or the tritium facility may be accompanied by a fire. Of special concern then is the effect of such a fire on the room air detritiation system. The smoke and combustion products could have a deleterious effect on the catalyst bed and a mechanical/physical effect on the operation of air blowers and/or compressors. A possible effect is the poisoning of the catalyst in the cleanup system. This could be a chemical poisoning or may be a physical phenomenon if these smoke particles deposit on the catalyst surface thus blocking the hydrogen isotopes and oxygen from the catalytic surface. These effects must be studied and the results carefully analyzed as we consider the design of these cleanup systems. A series of experiments investigating these effects will be the subject of future studies at TSTA. To date, none of these experiments have been initiated.

Surface Coatings and Surface Preparations

This is another area related to the ultimate efficiency of room air detritiation systems. In an accident situation, there will be many surfaces (walls, floors, equipment, gloveboxes, etc.) exposed to tritium. The overall efficiency of the cleanup will depend on how much of this tritium is sorbed on these surfaces, how easily this sorbed tritium is desorbed, how efficient these surfaces are at catalyzing the tritium-oxygen reaction to form water, and how strongly is this resultant water held on the surface.

A systematic study of the effect of various surface preparations and coatings (steel or aluminum liners, epoxy paints, latex paints, varnishes, etc.) on the sorption/desorption/catalysis processes is necessary if we are going to be in a position to provide adequate information on the selection of these materials to the fusion facility designers.

Cost/Benefit of Reducing Tritium Releases

Many decisions about room air detritiation systems--their sizing, design efficiency, and use--are influenced by that most elusive of concepts--the benefit of each successive decrement in environmental tritium releases. Or is cost/benefit even the best approach to deciding the lowest reasonably achievable levels (ALARA) from all standpoints--environmental, political, and economic?

If cost/benefit is the best approach, what should be used for the value of a man-rem of exposure avoided? How will the value assigned change with time? How should world doses be evaluated in dollars?

Or should room air detritiation systems be sized entirely by considerations of downtime in the facility following a spill? If so, at what rate should downtime be valued? The issues are complex and involve societal and programmatic judgments, in addition to technical ones.

TRITIUM HANDLING ISSUES

Standardization of Tritium Shipping Containers

There is, of course, a standard, approved, shipping container for tritium gas. This is the LP-50, a 50-l gas cylinder with associated overpack, which is used by the US Department of Energy Laboratories. In a large scale fusion economy there may, however, be a requirement for larger shipping containers and for shipping tritium between sites as a solid metal tritide, for instance uranium tritide, UT_3. We must assure that if these different types and sizes of shipping containers are designed, tested and placed in operation, that there is a standardization of fittings for these designs. This includes not only the fittings for attaching the shipping container to the gas handling facility at a fusion site, but also must include standardization of flanges, etc. necessary to attach the containers to the gloveboxes used as secondary containment for tritium.

Component Reliability Statistics

For several reasons, the compilation of meaningful data on component reliability and system availability is important to fusion development efforts. The more immediate reason is to uncover and improve the unreliable links in fusion power generation. Down the line, the time will come when fusion plants must be sold based convincingly on the cost of power they produce. This in turn depends on the operating availability of the plants, with data to back it up.

The gathering of such data is always a compromise between the amount of data gathered, the ability to analyze the data, and the cost of gathering and analysis. There is ongoing work in this area at TSTA in cooperation with the Fusion Safety Laboratory at Idaho National Engineering Laboratory (INEL) and the Fusion Working Group on Availability Statistics. Data are needed both on failure rates and on time-to-repair.

Tritium Inventory and Accountability Requirements

Tritium inventory and accountability requirements are an often mentioned policy issue for the fusion program. Accountability to the accuracy (0.01 g) suggested in existing DOE orders is not possible in the extensive processing equipment needed for fusion machines. In a full-scale reactor where kilogram quantities of tritium are burned, bred, and processed through a fuel reprocessing system, the difficulties are increased.

For economic reasons, it seems certain that ultimately tritium accounting in fusion reactors must be done on-line and in situ without shutting down. This implies adapting for fusion fuels the on-line accounting methods that have been developed for fission fuel reprocessing plants. Access at Los Alamos to the developers of these on-line methods and to the fusion fuel loop make TSTA a logical place for the adaptation and testing. Instrumentation appropriate for this work is currently under development.

At some stage, the real accounting requirements for fusion reactors must be set. The better the data base on accounting is at that time, the more likely it is that the requirements set will be both effective and feasible.

CONCLUSION

The above list of unresolved issues indicates that there is a considerable amount of research and development yet to be accomplished in fusion-related tritium technology. This paper does not address the very considerable number of issues which have been resolved by previous research and development. In general, tritium technology is a technology of sufficient maturity that it will not be a pacing item in the development of fusion energy.

REFERENCE

1. J. L. Anderson, Tritium Handling Requirements and Development for Fusion," Proc. of IEEE, 698, 1069-1080 (1981).